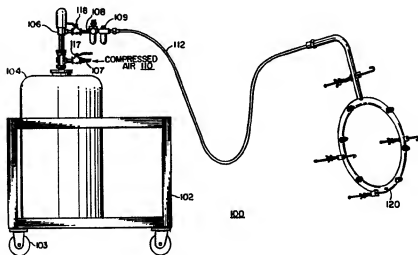




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

| | | |
|--|-----------|---|
| (51) International Patent Classification ⁵ : B08B 3/02, 3/10 | A1 | (11) International Publication Number: WO 92/14557 (43) International Publication Date: 3 September 1992 (03.09.92) |
| <p>(21) International Application Number: PCT/US92/01222</p> <p>(22) International Filing Date: 13 February 1992 (13.02.92)</p> <p>(30) Priority data: 654,812 13 February 1991 (13.02.91) US</p> <p>(71) Applicant: SERMATECH, INC. [US/US]; 155 South Limerick Road, Limerick, PA 19468 (US).</p> <p>(72) Inventor: TASSONE, Bruce, A. ; 1722 Ridgeway Road, Havertown, PA 19 (US).</p> <p>(74) Agents: MACKIEWICZ, John, J. et al.; Woodcock Wasburn Kurtz Mackiewicz & Norris, One Liberty Place, 46th Floor, Philadelphia, PA 19103 (US).</p> | | <p>(81) Designated States: AT (European patent), BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), LU (European patent), MC (European patent), NL (European patent), SE (European patent).</p> <p>Published <i>With international search report.</i> <i>With amended claims and statement.</i></p> |

(54) Title: METHOD AND APPARATUS FOR INJECTING A SURFACTANT-BASED CLEANING FLUID INTO AN OPERATING GAS TURBINE



(57) Abstract

Methods and apparatus (100) for cleaning operating gas turbines utilizing surfactant-based cleaning fluids are disclosed. It has been found that surfactant based cleaning fluids can effectively clean contaminant deposits from the interior surfaces of gas turbines and are particularly adapted to use while the turbine is operating. The present invention provides a tank (104), pump (106) and manifold (120) adapted to spray surfactant-based cleaning fluids into gas turbines. The manifold (120) of the present invention is preferably ring-shaped and contains a plurality of nozzles disposed so as to create a cone-shaped spray pattern. In a preferred embodiment, the manifold (120) is mounted to the turbine using a plurality of spring-loaded hooks which effectively isolate the manifold from the vibration of the turbine.

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**METHOD AND APPARATUS FOR INJECTING A SURFACTANT-BASED
CLEANING FLUID INTO AN OPERATING GAS TURBINE**

The present invention relates to the cleaning and maintenance of gas turbines and, more specifically, to a method and apparatus for delivering cleaning solution into an operating gas turbine to remove contaminants and reduce corrosion.

Background of the Invention

Turbine engines are used in a variety of applications including many types of marine vessels and aircraft, military and commercial, large and small. The operation of a gas turbine involves the intake of a large quantity of air through the turbine. Since the high velocity and high volume of intake make filtering the air difficult, airborne contaminants are drawn into the turbine along with the intake air. Moreover, even if filtering of the intake air were practical, gaseous contaminants would still be forced into the turbine. For example, in a marine environment, turbine intake gases may comprise a variety of contaminants such as salt spray, oil mist and environmental pollutants. Similarly, on land, air pollutants, fuel impurities, dust and other contaminants all may enter the turbine. Any turbine exposed to contaminants over time will build up soft deposits of contamination on its interior surfaces.

After the air and the contaminants it contains have passed through the intake, the restrictions within the compressor section of the turbine, coupled with the elevated temperatures therein further promote the formation of corrosion and the deposition of particulate contaminants on

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the interior surfaces of the turbine. The heat within the turbine bakes these deposits onto the interior surfaces of the turbine, where they cause a reduction of the engine power and a consequent decrease in economy. The corrosion caused by
5 salt or other corrosive substances decreases performance and greatly reduces engine life. In particular, salt crystals combined with other contaminants can work their way into bushings, bearings and other components machined to close tolerances. The ensuing abrasive action creates premature
10 wear of these components, leading ultimately to their failure. It would therefore be desirable to regularly clean soft deposits from the interior surfaces of gas turbines, to remove any baked on deposits and smooth corroded surfaces, and to inhibit further corrosion.

15 One known technique for cleaning turbines involves spraying a solvent-based cleaning solution into the turbine and then "cranking" the engine at a reduced speed to disperse the solvent. The solvents used in such applications are usually highly flammable petroleum distillates that cannot
20 safely be used in an operating turbine. Moreover, the low molecular weight of these solvents permits their evaporation in the early stages of the compressor so that they never reach, and consequently fail to clean, the final compressor stages. Petroleum solvent-based cleaning fluids are also
25 corrosive and toxic. These properties cause storage problems and present a risk to human and environmental safety. Additionally, because solvent-based cleaning solutions dissolve only certain types of contaminants, they must be mixed with water so that organic deposits, carbon, and
30 inorganic salts can be dissolved and removed. This requirement further tends to limit the effectiveness of solvent-based cleaning solutions, since the contaminants dissolved in the first compressor stages are carried to later stages and are deposited when the solvents and water flash
35 off. Injecting solvents and "cold cranking" at reduced speeds also does not generate sufficient airflow to properly

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distribute the solvents, leaving the later stages of the turbine fouled and corroded.

Despite the drawbacks of cold cranking washes, others have disclosed apparatus specially adapted to spraying solvent-based turbine cleaning fluids for use in a cold cranking wash. For example, U.S. patent 4,059,123--Bartos et al., discloses a cart containing a compressor along with pressurized bottles of solvent, cleaner, preservative and water. An internal combustion engine mounted on the cart powers both the compressor and an alternator. A storage battery, charged by the alternator, cranks the turbine at ten percent of its rated speed during cleaning. The patent discloses a spray ring that may be clamped to the hub shroud of the turbine which ring comprises two arcuate tube sections connected by a T-section. Using a plurality of orifices formed in the tubular walls of the arcuate sections, solvents and the other fluids are sprayed in a cylindrical pattern, perpendicular to the plane of the arcuate sections and aligned with the centerline axis of the turbine. U.S. patent 4,196,020--Hornak et al., discloses an engine wash spray apparatus adapted to spray water and solvent-based cleaning fluids into gas turbine engines. The apparatus disclosed comprises several spray nozzles and a specifically configured manifold that locates the nozzles relative to the struts and other supporting structures of the intake. The spray nozzles themselves have two parallel flat projections which ensure that a spray pattern having the shape of a rectangular pyramid is created by each nozzle.

Because of the disadvantages inherent in using solvent-based cleaning solutions to clean gas turbines, other formulations of cleaning solutions effective for this purpose have been devised. For example, U.S. patent 4,808,235--Woodson et al., discloses turbine cleaning solutions comprised of a glycol ether, a nonionic surfactant, a cationic surfactant and water. Similarly, the composition R-MC sold by ECT, Inc. of King of Prussia, PA is a gas turbine cleaning

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fluid comprised of cationic surfactant, which is non-flammable, non-toxic and biodegradable, permitting the entire interior of the turbine to be cleaned while operating, i.e., on-line cleaning. Surfactant-based gas turbine cleaning compositions provide a solution to fouling and corrosion problems by cleaning turbines of soft deposits and removing built up, baked on deposits from existing fouled and corroded surfaces. The cleaning process may be undertaken while the turbine is operating, thereby enhancing the distribution of the cleaning fluid throughout the turbine.

In addition to surfactant-based cleaning solutions being preferred because they can be used "on-line," they have also been found to be more effective. In tests, it has been found that turbine engines cleaned while operating using surfactant-based cleaning fluids exhibited dramatic reductions of the salt and dirt deposits throughout the compressor, and a significant reduction of the carbon deposits in the combustion and high pressure turbine sections of the engine. As pointed out above, the accumulation of contaminants within the compressor can be particularly troublesome, reducing power, increasing operating temperature and fuel consumption, and causing stalling and vibration during acceleration. However, since surfactant-based cleaning solutions chemically combine with contaminants, the higher temperatures in the latter stages of the turbine make chemical reactions more effective. Even if a surfactant-based cleaning fluid is volatilized by the heat within the turbine, baked on deposits in the combustion chamber and elsewhere are cleaned by surfactant entrained in the air, and are carried away via the gas stream of the exhaust.

It is thus an object of the present invention to provide a method and apparatus specifically devised to inject surfactant-based cleaning solutions into operating gas turbines.

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A further object of the present invention is to provide a method and apparatus which evenly and effectively distribute a spray of surfactant-based cleaning fluid into the intake of a gas turbine.

- 5 Another object of the present invention is to mount spraying apparatus to a gas turbine in a manner unaffected by the operation of the turbine.

Summary of the Invention

- These and other objects may be attained in accordance with the present invention by apparatus for cleaning an operating turbine engine to effect removal of contaminants and reduce corrosion of the engine parts comprising a reservoir of a surfactant-based cleaning fluid, a pump cooperatively constructed and arranged with said reservoir for maintaining the cleaning fluid in said reservoir at an elevated pressure, and a manifold cooperatively associated with said pump for directing said fluid at a sufficiently elevated pressure into contact with the interior surfaces of said operating turbine to reduce the contaminant deposits on said interior surfaces. In a preferred form of the invention, the reservoir of the surfactant-based cleaning fluid comprises a drum with a suitable drum pump capable of pressurizing the cleaning fluid to a suitably elevated value that will facilitate an even spray of the fluid onto the interior surfaces of the turbine. In accordance with one form of the invention, such spraying may be achieved by the use of a manifold, which may be tubular, and which comprises a plurality of nozzles so constructed and arranged on the manifold as to evenly spray the fluid into the turbine and into contact with its interior surfaces containing the contaminant deposits that are to be removed. In accordance with a preferred form of the invention, the manifold is equipped with a suitable connection or connections adapted to attach the manifold assembly directly to the turbine, and thereby facilitate the deposition of the desired cleaning fluid into contact with the internal surfaces of the turbine

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that require cleaning. Such connection may advantageously be effected with a plurality of suitable fasteners, such as hooks, for example, for releasably attaching the manifold assembly to the turbine. According to a preferred form of the invention, the fasteners, or hooks, include a flexibly yieldable or compressible section such that, during a cleaning operation, the manifold secured to the engine through such fasteners is, by virtue of the flexibly yieldable or compressible sections, substantially isolated from the vibrations of the operating turbine that occur during the cleaning cycle. In a preferred embodiment, each of the fasteners comprises a rod having a hook shaped portion at one end, a compressible spring, and an adjusting device such as a wing nut, for example, connecting the manifold with the other end of the hook. Upon engagement of the hook-shaped portion with the turbine, the spring urges the manifold against the turbine structure. Preferably, the manifold is substantially circular in shape, and has a mounting arm containing a connection to the drum pump. Preferably, the drum pump itself comprises an inlet valve for regulating a source of compressed air, an outlet connection comprising an outlet valve for regulating the flow of pressurized cleaning fluid, and a filter for removing contaminants from the pressurized fluid.

In a preferred embodiment, each of the nozzles has an orifice disposed at an angle to the center line axis of the turbine. In operation, the combined spray pattern of all of the nozzles forms a substantially cone-shaped spray. The cleaning fluid used in accordance with the present invention is most preferably pressurized to a pressure of about one hundred (100) pounds per square inch (psi) and most preferably is a surfactant-based fluid consisting essentially of a cationic surfactant and water. However, other pressures may be used.

The method for cleaning a turbine engine to effect removal of contaminant deposits and reduce corrosion of the engine parts in accordance with the present invention

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comprises pressurizing a surfactant-based cleaning fluid maintained in a reservoir zone, directing the cleaning fluid from the pressurized reservoir zone to a distribution zone maintained in close proximity to the intake of an operating turbine engine whose interior surfaces are to be cleaned, dispersing the surfactant-based cleaning fluid in the distribution zone into a plurality of streams, and directing each of such streams onto the interior surfaces of the operating turbine engine at an angle to the centerline axis of the turbine thereby to reduce the contaminant deposits on the interior surfaces of the turbine engine.

Brief Description of the Drawings

FIG. 1 is an elevation view of spray cleaning apparatus made in accordance with the present invention.

FIG. 2 is a plan view of the ring-shaped manifold of the present invention.

FIG. 3 is an elevation view of the apparatus illustrated in FIG. 2.

Detailed Description of the Preferred Embodiments

Referring to FIG. 1, there is shown a preferred embodiment of the apparatus of the present invention 100. A cart 102 is provided which contains a reservoir of surfactant-based cleaning fluid suitable for cleaning gas turbines contained in a suitable container, such as drum 104. In certain embodiments, the cart 102 will be provided with casters 103 to enable the apparatus of the present invention to be moved into the proximity of the gas turbine being cleaned. In other embodiments where it may be desirable to utilize a stationary drum, the cart 102 may be replaced by a cradle for restraining the drum 104, or may be dispensed with altogether if the drum 104 is sufficiently free standing. As shown, the drum 104 is provided with a drum pump assembly 106 which takes pressurized air and causes the flow of pressurized fluid. Pressure on the cleaning fluid

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in drum 104 is provided by a source of compressed air 110 (not illustrated) which may either be mounted in the cart 102 or remotely located. In a preferred embodiment, the present invention provides surfactant-based cleaning fluid pressurized to about 100 psi. Other pressures in this order of magnitude, i.e., between 60-150 psi will also be useful in certain embodiments. The source of compressed air 110 is connected to the drum pump 106 at an inlet connection 107, which most preferably includes a ball valve 117 and other necessary connecting hardware. Similarly, the outlet connection 108 is most preferably comprised of a ball valve 118 and also preferably includes filters and traps 109 as shown. The outlet connection 108 is connected to a flexible hose 112 which carries pressurized surfactant-based cleaning fluid to the ring-shaped manifold 120. The flexible hose 112 is preferably a stainless steel-jacket flexible hose, encased in a rubber outer jacket, suitable for carrying pressurized fluids in the environment of the turbine being cleaned.

As seen in FIG. 2, the ring-shaped manifold 120 of the present invention is most preferably a continuous, tubular apparatus having a plurality of spaced-apart spray nozzles 122. In the embodiment illustrated, six nozzles 122 are equally spaced around the circumference of the manifold 120. In another preferred embodiment, not illustrated, twelve nozzles 122 are provided. Each nozzle 122 has an orifice which is disposed at an angle to the centerline of the turbine such that when fluid is pumped through the orifices, the combined spray patterns of the nozzles 122 will form a cone-shaped spray suitable for introduction into the intake of an operating turbine. As will be appreciated by those skilled in the art, the exact number and spacing of the nozzles will depend to some extent upon the amount of cleaning fluid that must be delivered into the intake, as well as the airflow at the intake and the concentration and formulation of the surfactant-based cleaning fluid.

Several fasteners, or hooks 128 for mounting the manifold 120 to the turbine are also provided. As explained

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in greater detail below, in a preferred embodiment, these hooks permit the manifold to be flexibly mounted to the turbine. A mounting arm 124 extends from the manifold 120, permitting the manifold 120 to be handled and correctly
5 positioned. The mounting arm 124 includes also a hook 128. In a preferred embodiment, the manifold 120 is an integral, welded stainless steel assembly, including both the ring-shaped section and the mounting arm 124. However, those of ordinary skill will readily appreciate that the manifold
10 assembly may be cast, formed or otherwise fabricated from any number of individual parts which are later welded, brazed or affixed together, or joined using mechanical fasteners or threaded connections.

Referring now to FIG. 3, there is illustrated an
15 elevation view of the manifold 120 illustrated in FIG. 2. As shown, the mounting arm 124 is most preferably bent at approximately a right angle to the plane of the ring-shaped portion of the manifold 120 to provide a convenient position for a connection 126 for joining the flexible hose 122 to the
20 manifold 120. The connection 126 is preferably a quick-disconnect fitting, suitable for pressurized applications. FIG. 3 also illustrates the fasteners or hooks 128 described above, used to fasten the manifold 120 to the turbine in a flexible fashion. In a preferred embodiment, the hooks 128
25 comprise a hook-shaped portion 129 of a rod, or other structure adapted to engage a portion of the turbine. A coil spring 130 or other flexible means is provided and is adjustably fastened by a wing nut 132 or the like, in a position whereby the spring 130 will be compressed and
30 flexibly urge the manifold 120 against the turbine when installed. The wing nut 132 or similar adjusting means may be threaded up or down the hooks 128 to adjust the relative distance between the hook-shaped portion 129 and the manifold 120. When properly adjusted, the engagement of the wing nut
35 132 and the spring will produce a compressible anchorage when the hook portion 129 is engaged with the turbine structure.

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Those skilled in the art will realize that since the present invention is intended to be used when the turbine is operating, the provision of a flexible coupling means is important, since the vibrations imparted to the manifold 120 will vary with turbine speed and the overall condition of the turbine, e.g., some turbines may suffer from excessive vibration at operating speeds prior to cleaning. Therefore, it is desirable to dynamically isolate the manifold 120 from the turbine, and damp any vibrations transferred to the greatest extent possible.

The present invention also provides a method of cleaning operating gas turbines using surfactant-based cleaning fluids. First, a quantity of pressurized cleaning fluid is supplied and a manifold connected to the fluid supply is attached to the turbine. In a preferred embodiment, the connection of the manifold to the turbine is created by one or more flexible hook means. The pressurized fluid is then transported to the manifold and then to a plurality of nozzles that spray the pressurized fluid into the turbine. Preferably, the fluid is sprayed in streams which are disposed at an angle to the centerline axis of the turbine to form a cone-shaped spray pattern.

Although certain embodiments of the present invention have been set forth with particularity, the present invention is not limited thereby. Numerous variations and modifications will present themselves to those skilled in the art upon review of the present specification and the drawings relating thereto. For example, numerous techniques for flexibly mounting the manifold may be devised, all of which effectively isolate the nozzles on the associated structure from excessive vibration. Accordingly, reference should be made to the appended claims in order to ascertain the scope of the present invention.

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What is claimed is:

1. Apparatus for cleaning a turbine engine to effect removal of contaminants and reduce corrosion of the engine parts comprising:

5 a reservoir of a surfactant-based cleaning fluid;

 a pump constructed and arranged with said reservoir for withdrawing the cleaning fluid from said reservoir and placing it at an elevated pressure; and

10

 a manifold cooperatively associated with said pump for directing the pressurized cleaning fluid into the intake of an operating turbine engine and into contact with the interior surfaces thereof to reduce the contaminant deposits on said surfaces.

15

2. The apparatus of claim 1, wherein the manifold further comprises a plurality of fasteners, each of the fasteners comprising a flexible section, whereby the manifold is mounted to the turbine and is substantially isolated from

20 the vibration of the turbine while the turbine is operating.

3. The apparatus of claim 2, wherein each of the fasteners comprises a rod having a hook-shaped portion at a first end and a compressible spring means adjustably connected between the manifold and a second end, whereby, upon

25 engagement of the hook-shaped portion with the turbine structure, the spring means urges the manifold against the turbine structure.

4. The apparatus of claim 1, wherein the manifold comprises a substantially circular portion and a mounting arm

30 for attaching the manifold to the turbine extending from the substantially circular portion.

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5. The apparatus of claim 4, wherein the mounting arm further comprises means for connecting the manifold to the drum pump means.

6. The apparatus of claim 5, wherein the means for
5 connecting the manifold to the drum pump is a quick disconnect fitting.

7. The apparatus of claim 1, wherein the pump
comprises and inlet valve means for regulating a source of
compressed air and an outlet connection comprising an outlet
10 valve means for regulating the flow of pressurized fluid and
filter means for removing contaminants from the pressurized
fluid.

8. The apparatus of claim 1, further comprising a
plurality of nozzles, wherein each nozzle has an orifice
15 adapted to direct a spray of the cleaning fluid at an angle
to the centerline axis of the turbine, whereby the combined
spray pattern of the nozzles is substantially cone-shaped.

9. Cleaning apparatus for injecting a surfactant-
based cleaning fluid into the intake of an operating gas
20 turbine, comprising:

drum containing a quantity of a surfactant-
based cleaning fluid;

25 pump for pressurizing the fluid within the
drum means, the pump comprising an inlet a valve
for regulating a source of compressed air and an
outlet connection comprising an outlet valve means
for regulating the flow of pressurized fluid, and
filter means for removing contaminants from the
pressurized fluid;

30 a substantially circular tubular manifold for
injecting the pressurized fluid, the manifold being
in fluid-tight communication with the pump and
comprising a plurality of equally spaced nozzle

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means for evenly spraying the fluid into the turbine, each of the nozzle means having an orifice disposed at an angle to the centerline of the turbine, the manifold further comprising a plurality of hook means for compliantly attaching the manifold to the turbine, whereby the combined spray pattern of the nozzle means is substantially cone-shaped.

10. The apparatus of claim 9, wherein each of the hook means comprises a compliant section, whereby while the turbine is operating, the manifold is substantially isolated from the vibration of the turbine.

11. The apparatus of claim 10, wherein each of the hook means comprises a rod having a hook-shaped portion at a first end and a spring means and adjusting means adjustably connected between the manifold and a second end, whereby, upon engagement of the hook-shaped portion with the turbine structure, the spring means urges the manifold against the turbine structure.

12. The apparatus of claim 11, wherein the spring means comprises a coil spring wound around the hook means and the adjusting means comprises a wing nut threaded on to a portion of the hook means.

13. The apparatus of claim 9, wherein the fluid is pressurized to a pressure of about one hundred (100) pounds per square inch (psi).

14. The apparatus of claim 9, wherein the surfactant-based solvent consists essentially of a cationic surfactant and water.

15. A method for cleaning a turbine engine to effect removal of contaminant deposits and reduce corrosion of the engine parts comprising:

- 5 pressurizing a surfactant-based cleaning fluid maintained in a reservoir zone,
 directing said cleaning fluid from said pressurized reservoir zone to a distribution zone maintained in close proximity to the intake of an operating turbine engine whose interior surfaces
10 are to be cleaned,
 dispersing said surfactant-based cleaning fluid in said distribution zone into a plurality of streams,
 directing each of said plurality of streams
15 onto the interior surfaces of said operating turbine engine at an angle to the centerline axis of the turbine
 thereby reducing the contaminant deposits on said interior surfaces.

- 20 16. The method of claim 15, wherein said pressurizing step produces a pressure of at least about one hundred (100) pounds per square inch (psi) within said reservoir zone.

17. The method of claim 15, wherein said dispersing
25 step comprises creating said plurality of fluid streams in disposed around a circumference.

18. The method of claim 15, wherein the step of dispensing the surfactant-based cleaning fluid comprises connecting a manifold to the turbine by attaching one or more
30 fasteners to the turbine structure.

19. The method of claim 18, wherein the step of connecting a manifold to the turbine comprises affixing a plurality of flexible fasteners to the turbine structure.

AMENDED CLAIMS

[received by the International Bureau
on 27 July 1992 (27.06.92),
original claims 15 and 18 amended; new claims 20-24 added;
remaining claims unchanged (2 pages)]

15. A method for cleaning an operating turbine engine to effect removal of contaminant deposits and reduce corrosion of the engine parts comprising:

5 pressurizing a cleaning fluid comprising a
 surfactant and maintained in a reservoir zone,
 directing said cleaning fluid from said reservoir
 zone to a distribution zone maintained in
 close proximity to the intake of said
 operating turbine engine whose interior
10 surfaces are to be cleaned,
 dispersing said cleaning fluid in said distribution
 zone into a plurality of streams,
 directing each of said plurality of streams onto
 the interior surfaces of said operating turbine
15 engine,
 thereby reducing the contaminant deposits on said
interior surfaces.

16. The method of claim 15, wherein said
pressurizing step produces a pressure of at least about one
20 hundred (100) pounds per square inch (psi) within said
reservoir zone.

17. The method of claim 15, wherein said
dispersing step comprises creating said plurality of fluid
streams in disposed around a circumference.

25 18. The method of claim 15, wherein the step of
dispensing the cleaning fluid comprises connecting a manifold
to the turbine by attaching one or more fasteners to the
turbine structure.

19. The method of claim 18, wherein the step of
30 connecting a manifold to the turbine comprises affixing a
plurality of flexible fasteners to the turbine structure.

20. The method of claim 15 wherein the cleaning fluid comprises an aqueous solution of an anionic surfactant.

21. The method of claim 15 wherein the cleaning fluid comprises an aqueous solution of a cationic surfactant.

5 22. The method of claim 15 wherein the cleaning fluid comprises an aqueous solution of glycol ether, a nonionic surfactant, a cationic surfactant.

23. The method of claim 15, wherein the turbine engine has a centerline and the step of directing said
10 plurality of streams comprises the step of directing the streams toward the centerline.

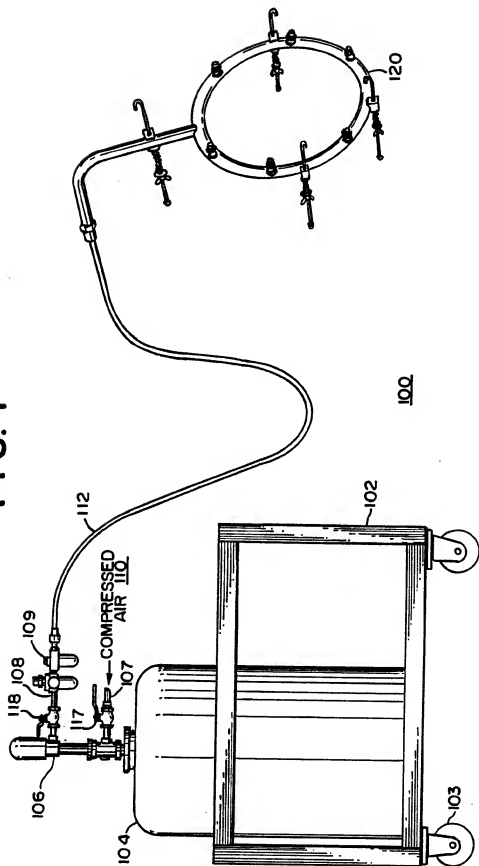
24. The method of claim 15, wherein the step of directing the cleaning fluid comprises the step of affixing a manifold comprising a plurality of nozzles for creating a
15 plurality of streams, wherein said affixing step comprises connecting one or more hooks that are compliantly attached to the manifold to the turbine, whereby vibrations from the operating turbine are substantially prevented from being transferred to the manifold.

STATEMENT UNDER ARTICLE 19

The foregoing amendments are submitted for substantially the same reasons that corresponding amendments were made in U.S. Application Serial No. 654,812 filed February 13, 1991. In an Office Action issued on January 17, 1992 (Paper No. 3) in that application, the claims were rejected as being indefinite and in view of the Bartos et al., Hornak et al. and Woodson et al. references cited in the Search Report. As amended, claim 15 now recites that a cleaning fluid comprising a surfactant is sprayed into an operating engine. These steps are neither disclosed nor suggested in the applied references.

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FIG. 1



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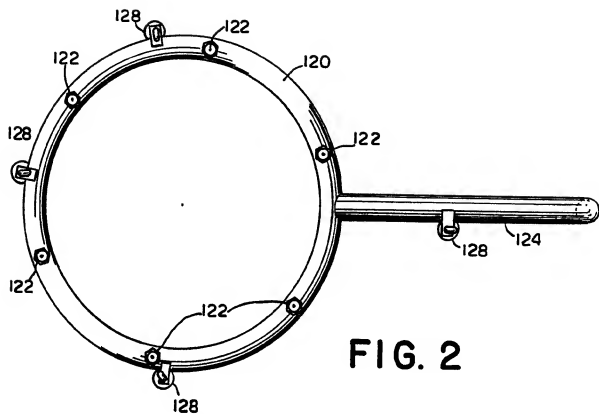


FIG. 2

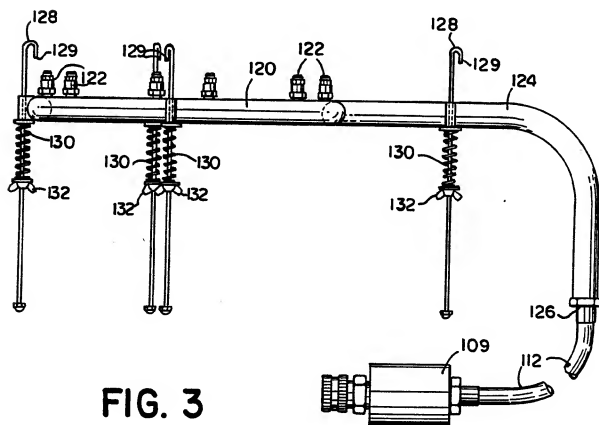


FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US92/01222

I. CLASSIFICATION OF SUBJECT MATTER (To report classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC
 INT. CL.³ B08B 3/02; B08B 3/10
 U.S. 134/22.12, 22.14, 32,33,34,166R,167R,169A

II. FIELDS SEARCHED

Minimum Documentation Searched

| Classification System | Classification Symbols |
|-----------------------|--|
| U.S. | 134/22.1, 22.12,22.14,22.18,22.19,24,32,33,34,40,166R 134/167R,169A; 415/110,117,121.3 |

Documentation Searched other than Minimum Documentation
 to the extent that such documents are included in the fields searched

III. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of Document, with indication, where appropriate, of the relevant passages | Relevant to Claim No. 1 |
|------------|--|-------------------------|
| X | US, A, 4,059,123 (BATTOS) 22 NOVEMBER 1977 Sec col. 5 lines 5-33, also figures 5 & 6 | 1,2,4-8,15, 17-19 |
| X | US, A, 4,196,020 (HORMAK et al) See col. 3, lines 21-45 01 APRIL 1980 | 16 |
| X | US, A, 4,808,235 (WOODSON et al) See abstract and claims 28 FEBRUARY 1989 | 15 |
| A | US, A, 3,779,213 (KNUDSEN) 18 DECEMBER 1973 | |
| A | US, A, 3,623,668 (FRIED) 30 NOVEMBER 1971 | |
| A | US, A, 2,974,925 (FREGHE et al) 14 MARCH 1961 | |

* Special categories of cited documents:

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** later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

1. document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

2. document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

3. document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

29 APRIL 1992

International Searching Authority

ISA US

Date of Mailing of this International Search Report

27 MAY 1992

Signature of Authorized Officer

SAEED T. CHANDHRY